Effects of Cropping Systems on Runoff, Erosion and Nutrient Losses in the Moldavian Plateau, Romania

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1. Abstract

The experiments carried out at the Podu-Iloaiei Agricultural Research Station, during 1986-2007, had the following objectives: study of water runoff and soil losses by erosion in different crops; annual rate of erosion processes under the influence of anti-erosion protection of different crops; runoff and erosion influence on losses of organic matter and mineral elements from soil. The determination of runoff, soil, humus and nutritive elements losses by erosion in different crops was done by means of plots for loss control, which are isolated from the rest of the area by metallic walls and have basins and devices for division; we took water and soil samples from plots, for determining the partial turbidity and for analyses on chemical elements. The determination of runoff, soil, humus and nutritive elements losses on anti-erosion arranged fields was done on the whole area of the retention basin (159 ha), where experiments were conducted since 1982 on fields arranged with sod coverage and strips cultivated with crops. The erosion control was done by means of a hydrological station with triangular waste weir, rain gauge, recording rain gauge, limnigraph and devices for water and soil samples uptake during rainfalls. The mean annual soil losses by erosion, registered during 1986-2007, were of 0.298 t/ha in perennial grasses on the second growing year, 4.618 t/ha in beans, 9.176 t/ha in maize and 9.65 t/ha in sunflower. 25 years after slope arrangement with sod coverage and strips cultivated with crops, runoff was reduced by 38.5 %, compared to the unarranged fields, and soil losses diminished by 42 %. From the results obtained on erosion in different crop rotations, we have found that in 14% slope fields from the Moldavian Plateau, soil losses by erosion diminished below the allowable limit of 3-5 t/ha/year, only in case of 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil.

2. Introduction

The Directive 2006/42/EC proposes the identification of zones with erosion-degraded soils and organic matter in decline, for meeting the requirements of the United Nations Convention to Combat Desertification (UNCCD) in Northern Mediterranean and Central and Eastern European Country Parties. In Romania, soil erosion is the most expensive degradation process, which affects almost 63% of the total area and 56% of the arable area from Romania. Investigations on soil erosion process were conducted in very few zones, compared to the diversity of geomorphologic, soil, and climatic factors from our country. Investigations on the potential erosion, conditioned by geomorphologic, soil and climatic factors, have shown that in NE Romania, the mean soil losses by erosion were of 18.3 t/ha/year. The studies carried out on the effective erosion, based on direct determinations and complex analyses, have shown that in the entire NE zone, the effective erosion had a mean value of 4.8 t/ha/year. Investigations carried out until today give information on the anti-erosion effect of different crop rotations with breeding plants and the hydro-ameliorative works on the present rate of shallow erosion.

The investigations conducted by Lazarov showed that the mean annual rate of erosion on the arable lands from Bulgaria was of 4.76 t/ha and of 2.69 t/ha on improved arable lands. Soil losses by erosion on the fields ploughed on the upstream-downstream direction, which are cultivated with maize, are of 7.48 t/ha. In sunflower, cultivated with the conventional soil tillage system, the annual eroded soil was of 3.044 t/ha, and by wheat straw and green fertilizer incorporation into soil, erosion has decreased at 2.327 t/ha and 0.937 t/ha, respectively (Mitova, 2006). The favourable influence of reduced tillage system and of crop residues on soil erosion was also signaled by Lal, (2006). He showed that in no-tillage system, soil losses by erosion were close to the ones found in case of soil protection with 6 t/ha of mulch. Determinations carried out on a 9% slope Luvisol, in the Centre of Croatia, have shown that ploughing on the upstream-downstream direction has resulted in losing soil amounts by erosion, between 38.18 and 5.10 t/ha, according to crop, and in case of deep ploughing on the direction of level curves, between 5.25 and 0.18 t/ha (Kisic, 2006). On the loam soils from N Alabama, in maize cultivated with no-till system, the total phosphorus losses by erosion are of 2.4-2.1 kg/ha (Nyakatawa, 2006). On 8.5% slope fields from SW Finland, annual soil losses by erosion are of 5-6 t/ha and leached nitrogen and phosphorus amounts are of 15.0 and 1.1 kg/ha/year, respectively (Muukkonen, 2007).

In the experimental field from Dummerstorf, North-Eastern Germany, with mean annual rainfall amounts of 665 mm, potential evapotranspiration of 490 mm and mean air temperature of 8.2^{0}C, in the rotation maize – winter wheat – winter rape and reserve field, cultivated with 10% red clover (Trifolium pratense L.) and 90% perennial ryegrass (Lolium perenne L.) (2006), the annual amounts of leached NO_3-N were of 5.7 -16.9 kg/ha, during 2004-2005 (Tiemeyer, 2008). The incorporation into soil of 2471, 4942 and 9884 kg/ha of crop residues has resulted in diminishing the eroded soil by 64, 85 and 98%, respectively, compared with the areas where no crop residues were applied. The surface application of crop residues at amounts of 2471 and 4942 kg/ha has diminished eroded soil losses by 90 and 100%, respectively, as compared with the areas lacking crop residues (McCool et al., 1995). The investigations conducted by Lindstrom, in Minnesota, USA, have shown that 927, 1853 and 3706 kg/ha of crop residues, applied in maize crops, have determined the decrease of soil erosion until 6.177, 1.730 and 0.988 t/ha respectively, and water runoff decreased until 35.6, 25.4 and 22.9 mm, respectively. The long-term research works carried out by Wilson, have shown that removing residues from maize crops, at different rates, has determined the increase by 26-47% of soil losses by erosion.

3. Methods

The determination of runoff and soil losses by erosion was carried out by means of loss control plots with a collecting area of 100 m^2 (25x4 m) and by means of a hydrological section equipped with spillway and limnigraph and devices for sampling water and soil loss by erosion. Experiments were conducted on the hydrographic basin of Scobalteni, with a reception area of 159 ha, a mean altitude of 119.4 m, a mean slope of 14 % and a mean slope length of 250 m. The area of the hydrographic basin has been anti-erosion arranged since 1982, being used combined cropping systems made of sod rewetting and strip cultivation. The width of cultivated strips is of 200-250 m on 5-10% slopes, 100-150 m on 10-15 % slopes and 50-100 m on 15-18 % slopes. The augmentation data, which were obtained in plots at the scale of the Scobalteni catchment, allowed the soil erosion estimation on the entire area of the catchment, where the experiments are placed, too. The catchment is provided in the downstream section with triangular waste weir, limnigraph and devices for water and soil samplings. Total nitrogen, nitrate, phosphorus and potassium content were determined in soil and water samples, lost by erosion in different crops, thus establishing the losses of nutritive elements. The climate is temperate continental with large thermal amplitude and uneven and commonly torrential rainfall prevalent during the vegetative season. The climatic conditions in the Moldavian Plain were characterized by a mean multiannual temperature of 9.6 ^{o}C and a mean rainfall amount, on 80 years, of 559.2 mm, of which 161.2 mm during September-December, and 398 mm during January-August.

4. Results

Erosion is caused by many soil and climatic factors and strongly modified by human activities in agriculture, among which the growing system determines a great variability of this process. The erosion being unavoidable and the tolerance level of soil losses being of 3-4 t/ha/year, corresponding to the annual rate of soil renewal, the technologies applied must keep these limits under control. The results on runoff and soil losses by erosion in different crops, which were determined by means of runoff control plots, are shown in Table 1.

The results on runoff and soil losses by erosion in different crops, which were determined by means of runoff control plots have shown that, during 1986-2007, of the total of 559.2 mm rainfall, 392.4 mm (70.2 %) caused runoff between 6.2 mm in perennial grasses on the second growing season and 29.7 mm in sunflower. The annual soil losses by erosion registered at the same period were between 0.298 t/ha in perennial grasses on the second growing season and 9.650 t/ha in sunflower. In the last 21 years, erosion was within the “allowable limits” of 2 t/ha / year in perennial grasses, on the second growing season, and wheat.

Taking into account that the erosion process can not be avoided and that the tolerance level of soil annual losses is 3-5 t/ha, which correspond to the annual rate of soil renewal, soil annual mean losses by erosion, registered during 1986-2007, in maize (9.176 t/ha) and sunflower (9.650 t/ha) can result in destructing fertile soil layer in a few decades. In the second growth year, in perennial grasses, the annual mean soil losses by erosion were of 0.298 t/ha and on bare fallow plot, they were of 18.790 t/ha. At three and four year rotations, which include good and very good cover plants for protecting soil against erosion, the amount of eroded soil and nutritive elements lost by erosion were very close to the limit allowable for this area.

Erosion has affected soil fertility by removing once with eroded soil, high amounts of humus and mineral elements, which reached 17.4-17.7 kg/ha nitrogen, 1.1 kg/ha phosphorus and 2.3 kg/ha potassium, in maize and sunflower crops (Table 2). These amounts decreased very much at the same time with the increase in the structure of crops protecting soil against erosion, such as peas, wheat, alfalfa and perennial grasses. The results obtained on the potential erosion (conditioned by geo-morphological, soil and climate factors) have shown that on the uncovered by vegetation fields from the Moldavian Plateau, the average soil losses by erosion were of 18.79 t/ha/year, values corresponding to a moderate erosion risk.

From the investigations carried out on effective erosion, based on direct determinations, we found that the effective erosion in the Moldavian Plateau, in peas-wheat-maize rotation, had a mean value of 4.507 t/ha/year (Table 3). These elements were necessary for establishing the crop structure and dimensioning the anti- erosion works, which determine the decrease of soil erosion and water runoff, soil and nutrients losses below the limit corresponding to the natural capacity of annual soil recovering, of 3-5 t/ha/year of eroded soil.

The mean annual soil losses by erosion, registered in the hydrographical basin with slopes arranged with bench terraces and strips cultivated with crops, were between 0.179 t/ha in perennial grasses and 5.6 t/ha in sunflower. The mean annual runoff and soil losses by erosion registered on the entire hydrographic basin, 25 years after arrangement, were of 10.2 mm and 2.713 t/ha soil, respectively. Comparing these results to the ones obtained by means of control plots for unarranged areas, it was found that in case of small hydrographic basins, with 14 % mean slope, 25 years since the arrangement, while a crop structure of wheat 30 %, grain annual legumes 30 %, hoed plants 30 % and legumes and perennial grasses 10 % was used, the mean annual runoff diminished by 38.5 % and soil losses by 42.0 %, compared to anti-erosion unarranged areas (Table 4). The mean annual soil losses by erosion, registered during 1986-2007, were of 0.179 t/ha in perennial grasses on the second growing year, 2.67 t/ha in beans, 5.324 t/ha in maize and 5.6 t/ha in sunflower.

Table 1 Average annual runoff and soil losses by erosion registered in different crops

Crop	Rainfall that caused runoff, (mm)	Water Runoff, (mm)	Runoff Coeff.	Average Turbidity (g l-1)	Erosion (kg ha-1)
Peas	345.1	11.4	0.033	23.60	2690
Wheat	345.1	7.9	0.023	20.76	1640
Maize	392.4	28.4	0.072	32.31	9176
Sunflower	392.4	29.7	0.076	32.49	9650
Bean	345.1	16.2	0.047	28.51	4618
Ist year grasses	328.6	9.8	0.030	19.29	1890
IInd year grasses	286.0	6.2	0.022	4.81	298
Field	408.2	51.2	0.125	36.70	18790

Average annual rainfall registered during 1986-2007 = 559.2 mm

Table 2 Mean runoff, soil, humus and mineral elements losses by erosion in the Moldavian Plateau

Crop	Runoff Water (mm)	Eroded Soil (kg/ha)	Humus and mineral elements lost by erosion, kg/ha					
			Humus	N_t in runoff water	N_t in eroded soil	Total N	P-AL	K-AL
Field	51.2	18790	629.5	3.779	27.246	31.024	2.161	4.510
Sunflower	29.7	9650	323.3	2.768	14.668	17.436	1.110	2.364
Ist year perennial grasses	9.8	1890	62.9	0.894	2.797	3.691	0.217	0.471
IInd year perennial grasses	6.2	298	9.9	0.549	0.489	1.038	0.033	0.074
Maize	28.4	9176	308.3	2.624	15.049	17.673	1.028	2.294
Peas	11.4	2690	90.4	1.051	4.008	5.059	0.245	0.538
Wheat	7.9	1640	55.1	0.773	2.690	3.462	0.184	0.410
Beans	16.2	4618	155.2	1.510	7.250	8.760	0.411	0.924

5. Conclusions

Among all the processes of soil degradation in the Moldavian Plateau, erosion is the most damaging, causing the loss of mean annual soil amounts of 1.640 t/ha in wheat, 4.618 t/ha in beans, 1.89 t/ha in perennial grasses on the first growing year, 9.176 t/ha in maize and 9.6 t/ha in sunflower.

After 25 years since the anti-erosion arrangement was applied, with a crop structure of 30 % annual grain legumes, 30 % wheat, 30 % maize + sunflower and 10 % perennial grasses and legumes, the mean annual runoff diminished at 10.2 mm and soil losses at 2.713 t/ha/year.

Erosion affects soil fertility by removing together with eroded soil, significant humus and mineral element amounts, which reach 17.4-17.7 kg/ha of nitrogen, 1-2 kg/ha of phosphorus and 2-3 kg/ha of potassium in maize and sunflower crops, representing on the average between 10-15 % of the chemical fertilizers necessary for these crops.

From the results obtained on erosion in different crop rotations, we have found that in 14% slope fields from the Moldavian Plateau, soil losses by erosion diminished below the allowable limit of 3-5 t/ha/year only in case of 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil.

Table 3 Soil, humus and mineral elements losses by erosion in different crop rotations

Crop rotation	Eroded Soil (t/ha)	Humus (kg/ha)	Nitrogen (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Total NPK
Maize continuous cropping	9.176	308	17.673	1.028	2.294	20.995
Wheat – maize rotation	5.408	182	10.567	0.606	1.352	12.525
Peas – wheat – maize rotation	4.502	151	8.731	0.215	1.081	10.027
Peas – wheat – maize – sunflower + reserve field cultivated with legumes and perennial grasses	4.691	157	8.934	0.52	1.136	10.59
Peas – wheat – maize – sunflower + 2 reserve fields cultivated with legumes and perennial grasses	3.959	144	7.618	0.466	0.959	9.043
Peas – wheat – maize + reserve field cultivated with legumes and perennial grasses	3.451	116	6.808	0.486	0.829	8.123
Beans- wheat – maize+ 2 reserve fields cultivated with legumes and perennial grasses	3.206	108	6.394	0.338	0.755	7.487

Table 4 Runoff and soil losses on arranged and unarranged field with works for soil erosion control

Crop	Rainfall that caused runoff, (mm)	Water Runoff, (mm)	Runoff Rate	Average turbidity, (g l-1)	Erosion (t ha-1)
A. Unarranged field; average rainfall registered 559.2 mm (1986-2007)					
Peas	345.1	11.4	0.033	23.60	2690
Wheat	345.1	7.9	0.023	20.76	1640
Maize	392.4	28.4	0.072	32.31	9176
Sunflower	392.4	29.7	0.076	32.49	9650
Bean	345.1	16.2	0.047	28.51	4618
IInd year grasses	286,0	6.2	0.022	4.81	298
Average	**351.0**	**16.6**	**0.047**	**28.13**	**4679**
B. Field arranged with works for soil erosion control					
Peas	254	7,0	0.028	22.33	1563
Wheat	254	4.8	0.019	19.67	944
Maize	268	17.4	0.065	30.60	5324
Sunflower	268	18.2	0.068	30.77	5600
Bean	254	9.9	0.039	26.97	2670
IInd year grasses	178	3.8	0.021	4.71	179
Average	**246**	**10.2**	**0.040**	**22.5**	**2713**

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